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Elastic Behavior of Soil: Majority of the research during the first year was focussed on developing a resonant column testing system suitable for performing experiments on both sand and clay. The research effort concentrated on developing testing procedures for saturated cohesive soil. Methods were established to obtain uniform and repeatable specimens of Kaolin clay for a known stress history and initial void ratio. The end platens were suitably modified to avoid multiple degrees of freedom under resonance. Significant improvements were also made to automate the data acquisition and interpretation related to resonant column testing.

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Project Title: Experiments and Modeling of High Strain Rate Effects in Sands and Clays

AFOSR Grant: No. F49620-98-0166

Clarkson Grant: No. 97153 (375-660)

Principal Investigator:
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Newark, DE 19716

Co-Principal Investigator:
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Potsdam, NY 13699-5710.

Project Period: 12/15/1997 - 11/14/1999 (Project Initially funded for FY 98, FY 99, and FY 00, but prematurely terminated at the end of its second year due to the phasing out of the Particulate Mechanics Program of US-AFOSR).

Dr. Yamamuro's Student Supported: Mr. Antonio E. Abrantes Ph.D. Candidate. Expected to finish in 2001.

Summary: Antonio E. Abrantes is a Ph.D. student. He is expected to obtain his degree in 2002. He received support from this project in FY 98 and 99. He is currently funded under a National Defense Science and Engineering Graduate Fellowship. His contribution has been to examine strain rate effects in granular materials. He has developed a 5.5 meter tall gravity drop frame to load the soil specimens to very high strain rates. See Fig. 1 in appended figures. A weight is dropped from different heights through a guide tube to impact the specimen at different strain rates. It is anticipated that the maximum strain rates that this frame can produce will be larger than any currently available in the literature, where true stresses and strains are measured. He has also developed a square triaxial cell (flat-sided) that can withstand cell pressures up to 150 psig without significant deformations in the flat acrylic side panels. See Fig. 2 in the appended figures. The flat sides of the triaxial cell produces only very small symmetrical optical distortions in the vertical and horizontal directions as opposed to a cylindrical cell, which significantly distorts the image of the specimen. Thus, by using an internal dimensional frame of reference, the deformations of the specimen can be photographically captured through the cell wall with little error and a minimum of optical corrections.

Mr. Abrantes has been performing tests at various high strain rates on specimens composed of coral sand. Coral sand was chosen because it possesses significant time effects, especially at low densities. A high speed camera (up to 35,000 images per second) has been purchased on an NSF equipment grant (CMS 9721462) to capture the deformations of the specimen at very high strain rates. The specimen is encased in a latex rubber membrane that has target points drawn on it. Tests are performed on dry specimens, because saturated specimens would not allow enough time to sufficiently drain the specimen at the high strain rates and therefore undrained conditions would always prevail. The pore spaces in the specimen are evacuated with vacuum to ensure that no pore pressures are developed from air. The

photographs are digitized on a film digitizer purchased on the NSF equipment grant (CMS 9721462). Images can be digitized with resolutions up to 6000 x 8000 pixels, which result in very accurate measurements of strains. An example of a series of photographs taken with the high-speed camera and digitized is shown in Fig. 3 in the appended figures. The photographs are of a test specimen that was loaded at approximately 1,400 percent per second (2.5 meters per second loading velocity). The specimen is shown at different and increasing axial strain values. Sophisticated image analysis software has been purchased (MetaMorph). It is being utilized to track the targets on the specimens to calculate the local strain values near the middle of the specimen, where uniform strain conditions exist. The results of these experiments will be the first high strain rate tests on granular materials where the true stresses and complete 3D strains are measured. This data is essential to develop a comprehensive 3D time effects constitutive model. Testing is currently ongoing.

Fig. 4 shows the significant error that is induced by calculating axial strains on a global basis versus the more correct local strain value at the center of the specimen, where uniform strains are occuring. Fig. 5 shows the signficant differences in the three different methods to estimate the cross-sectional area used to calculate the stress in the specimen. Substantial error is induced if the traditional method is used, that is based on uniform strain assumptions.

Dr. Penumadu's Student Supported: Mr. Ian Hazen. Completed MS degree in 1999.

Summary: In the original proposal under the direction Dr. Dayakar Penumadu, two tasks wereproposed for: 1) determining the elastic behavior of soil, and 2) performing high stress and high strain rate experiments of soil. In order to satisfactorily complete these tasks, full time effort of a doctoral student for three years was required and thus requested in the original proposal.However, due to the phasing out of Particulate Mechanics Program of AFOSR, Co-PI receivedfunding only for the first year and the project was abruptly terminated. Thus, the present progress report includes the results from only the first year of research effort of the Co-PI and his student. Task-2 was not attempted because of the premature termination of the project.

ABSTRACT

Elastic Behavior of Soil: Majority of the research during the first year was focused on developing a resonant column testing system suitable for performing experiments on both sand and clay. The research effort concentrated on developing testing procedures for saturated cohesive soil. Methods were established to obtain uniform and repeatable specimens of Kaolin clay for a known stress history and initial void ratio. The end platens were suitably modified to avoid multiple degrees of freeedom under resonance. Significant improvements were also made to automate the data acquisition and interpretation related to resonant column testing.

A part of soil deformation under load is due to elastic deformation of the soil particles. Even though this constitutes only a small part of the total deformation, for accurate time dependent three dimensional modeling of soil behavior, it is essential to obtain reliable elastic parameters. Elastic deformation is often obscured by deformation resulting from slippage, rearrangement, and crushing of particles. Based on extensive laboratory data to date, the stress-strain relation for soils is purely elastic for small amplitude cyclic loading only. The upper limit of strain for elastic behavior is considered to be 0.001 percent. Resonant column testing system used in this study (Fig. 1) can apply such loading and isolate purely elastic stress-strain relation from the analysis of propagation of small amplitude stress waves.

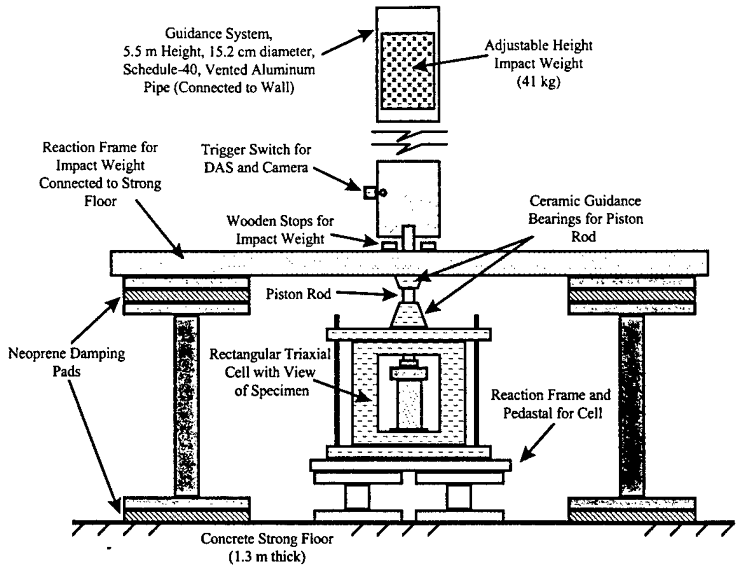

Figure 1: Major Components of Testing Apparatus

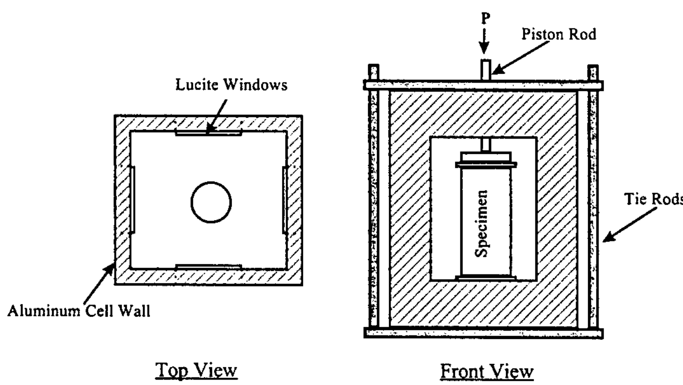

Figure 2: Triaxial Cell Used for Transient Testing

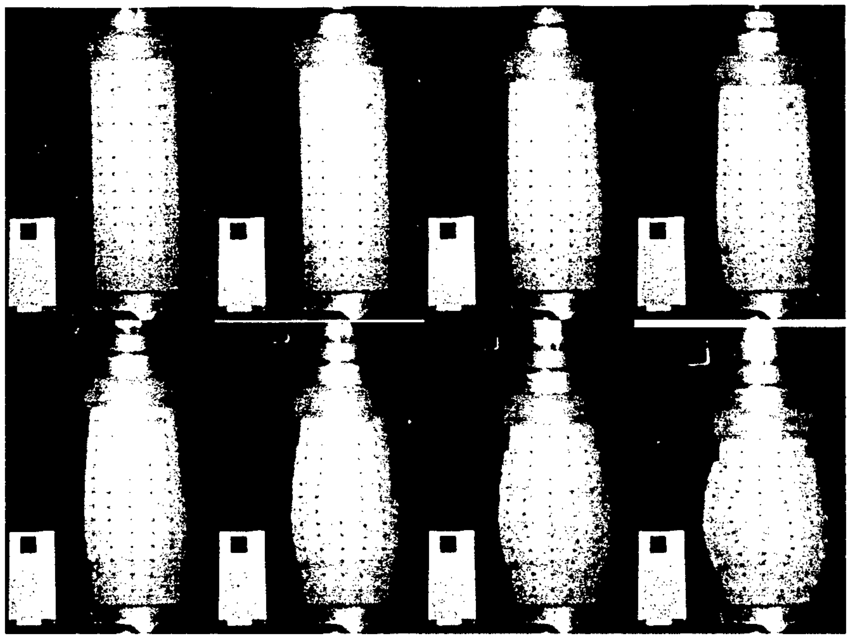

Figure 3: Deformation of a Soil Specimen under Transient Loading Conditions (Strain rate 1,400 %/Sec or 2.5 Meter/Sec); a) 0% axial strain, b) 3.5%, c) 13.0%, d) 16.3%, e) 20.1%, f) 26.1%, g) 32%, h) 42%.

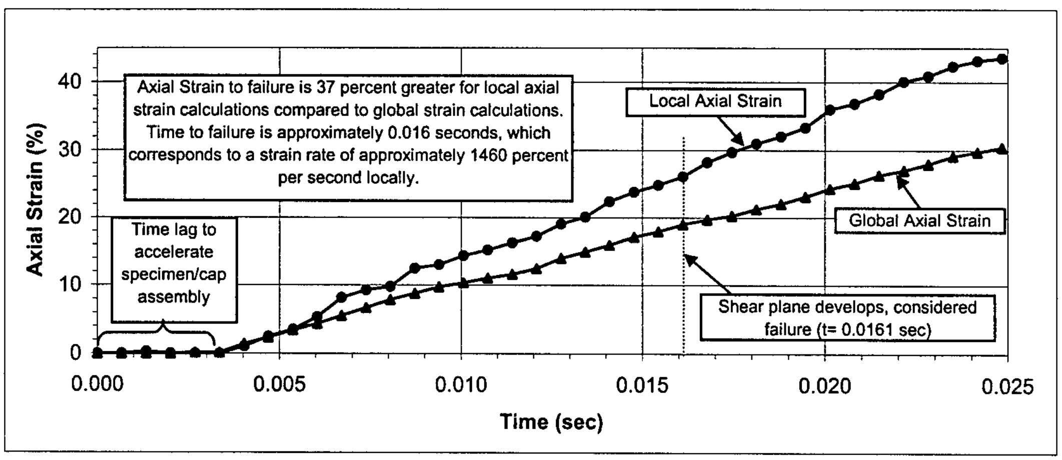

Figure 4: Comparison of Local and Global Axial Strain

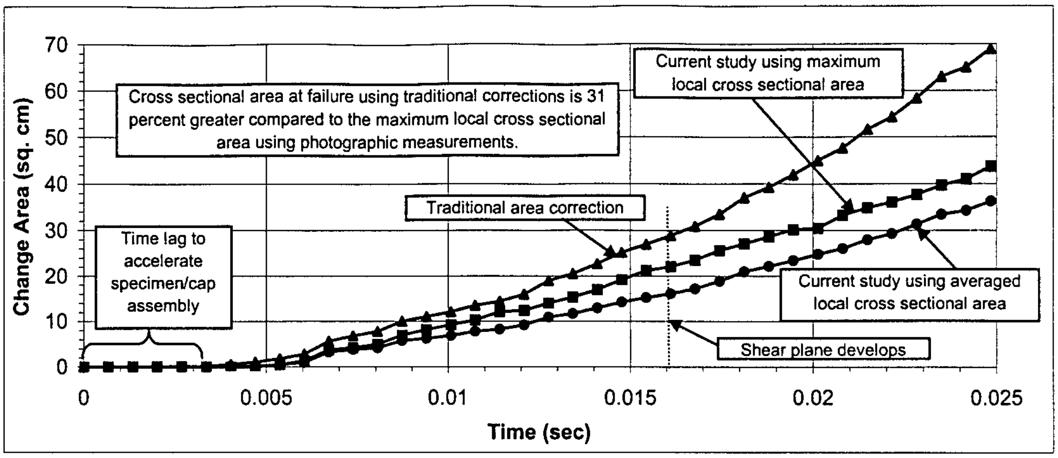

Figure 5: Comparison of Specimen Cross Sectional Area